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Titanium miniplate fixation for osteotomies in facial fibrous dysplasia – a histologic study of the screw/bone interface

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Abstract. In four patients who had osteotomies of the jaws affected by fibrous dysplasia (FD), screws embedded in bone blocks were removed at a re-entry operation 20 months postoperatively. Morphometric measurement of the bone density and calculation of the bone contact percentage were performed. Both normal and dysplastic bone were found to have some direct bone contact with the titanium screws. Although the bone contact percentage was higher in the normal bone when compared with FD, statistics failed to show any significant difference ($P>0.05$). The dysplastic bone healed well around the titanium screws without inflammatory reaction and direct dysplastic bone/screw contact was noted. Longer screws should be used in facial FD in order to compensate for the reduced bone contact percentage.

Key words: rigid fixation; osteotomy; fibrous dysplasia.

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Fibrous dysplasia (FD) is a developmental fibro-osseous condition which may affect one or more bones, resulting in disfigurement and loss of function. Facial FD usually affects the jaws; severe cases may extend to the cranial bones. Management may be conservative with surgical recontouring of the deformed bone for aesthetic improvement, or radical to combine aesthetic improvement with eradication of the lesion. Though the choice of treatment method remains controversial, the place of conservation surgery for lesions affecting the jaws is well accepted[3,5,15]. In cases affecting the facial bones and presenting with malocclusion and jaw disproportion, we have extended conservative recontouring surgery to include simultaneous osteotomies and repositioning of the affected maxilla and mandible, thus enhancing the aesthetic and functional result[20,21]. Titanium miniplates and screws were used for fixation of the dysplastic bone. Satisfactory clinical bony healing was obtained, and our preliminary report showed close proximity of the titanium screws to the dysplastic bone on histology[20]. The aim of this study is to assess histologically the screw–bone interface and compare the findings in fibrous dysplastic bone with those in normal bone.

Material and methods

Four adult patients presenting with facial FD and malocclusion underwent surgical recontouring and osteotomies of the jaws in the Department of Oral and Maxillofacial Surgery, University of Hong Kong (Table 1). Fixation after osteotomies was achieved by titanium miniplates and screws, resulting in satisfactory bony healing without clinical recurrence of the facial deformity or malocclusion. The plates and screws were removed under local anesthesia between 9 and 32 months (mean 20 months) after operation. The plates were sectioned and the screws removed *en bloc* with the surrounding bone (Fig. 1). A total of 13 titanium screws was harvested with fibrous dysplastic bone attached. In two of the patients, the miniplates from the contralateral normal side were also removed, and four screws removed in a similar manner served as control for comparison.

The specimens were fixed in 10% formalin solution and trimmed to a standard size with one screw inside each bone block. The specimens were then dehydrated through an ascending concentration of ethanol and treated for over 4 h in propylene oxide in vacuum. They were then embedded in pure epoxy resin (Taab 812 Resin Kit, Taab Laboratories Equipment Ltd, UK) and placed inside an oven maintained at 60°C for 48 h to complete the polymerization. The polymerized bone

Table 1. Clinical data of patients with fibrous dysplasia

Patient no.	Sex/age	Extent of FD	Osteotomies performed	Follow-up (months)	Biopsy site	Screws removed/ type of bone
1	F/30	Left mandible body and ramus	Wunderer, bilateral Schuchardt, Hofer, genioplasty	13	Left body of mandible	2 FD
2	M/32	Right zygoma, maxilla, and mandible	Right Schuchardt, mandibular posterior subapical	26	Right body and ramus of mandible	5 FD
3	M/25	Right body and ramus of mandible	Bilateral mandibular body step	32	Right and left bodies of mandible	4 FD 2 normal
4	F/22	Right maxilla and zygoma	Le Fort I, bilateral sagittal split, genioplasty	9	Right and left maxilla	2 FD 2 normal

FD=fibrous dysplasia.

blocks were trimmed along the midaxial plane of the screw and gradually ground down with carborandum paper (Microfine 1200, 3M, USA) to 80-μm thickness. The sections were polished and stained with 0.5% toluidine blue in sodium tetraborate for 5 min on a warm plate at 45°C. The stained sections were dried and mounted with Permount (Fisher, USA) on glass slides. The specimens were examined under a bright-field light microscope (Olympus BH-2, Japan) and a polarizing microscope (Orthoplan, Leitz, Germany).

Morphometric measurement of the specimens was performed with a computerized image analyzer (Videoplan version 2.1, Carl Zeiss, Germany). A standard area enclosing both the screw and bone (total area) was selected in each section; within this total area, separate digitization was performed for the titanium on the one hand, and for the bone area surrounding the screw on the other. The measurements were repeated three times, and the mean value was recorded. The bone density (BD) percentage was calculated by the following formula:

$$\text{Bone density (BD)} = \frac{\text{bone area}}{\text{total area} - \text{titanium area}} \times 100\%$$

The sagittal perimeter of each titanium screw section below the bone surface and the amount of bone in direct contact with the screw surface were also digitized. The percentage of bone contact with the titanium surface (BCP) was calculated by the following formula:

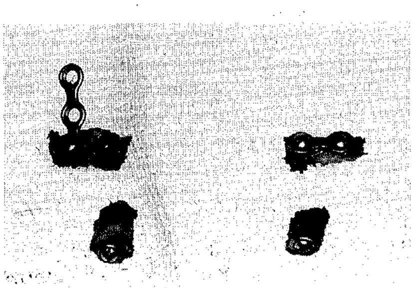

Fig. 1. Sample of specimens obtained at plate removal with bone covering screws.

$$\text{Bone contact \% (BCP)} = \frac{\text{direct bone contact}}{\text{titanium perimeter}} \times 100\%$$

Statistical comparison of the BD and BCP between the fibrous dysplastic and normal bone specimens was performed with the Mann-Whitney test where the result is significant if $P<0.05$.

Results

Light-microscopic findings

In all specimens of fibrous dysplastic bone, the classical histologic features of woven bone with irregular trabeculae in a cellular connective-tissue stroma were confirmed (Fig. 2a and c). Seven specimens also showed the presence of lamellar bone trabeculae characterized by cement lines or osteoblasts lining the surfaces. No acellular cementoid-like particles were observed. There were no inflammatory cells or increased vascularity around the titanium screws. A proportion of the titanium screw surface was in direct contact with the bony trabeculae in all specimens except two, where the bone tabeculae were noted to stop short of the screw, resulting in only connective-tissue contact with the whole perimeter.

In the normal bone specimens with the titanium *in situ*, dense mature lamellar bone trabeculae were noted (Fig. 2b and d). Woven bone and inflammatory reaction was absent around the screw. Direct bone contact with the titanium surface perimeter was observed. However, this did not occur along the whole screw, and a proportion of the surface was lined by connective-tissue capsule.

Morphometric analysis

In normal bone specimens, the density of the bone immediately adjacent to the screws was only marginally higher than for the dysplastic bone specimens (Table 2). The mean of the percent bone contact with the titanium surface was clearly higher in the normal bone when compared with dysplastic bone specimens (Table 3). However, both the BD and BCP failed to show statistically significant differences when the dysplastic

Table 2. Bone density in fibrous dysplastic and normal bone

Mean value	Total area (mm^2)	Titanium area (mm^2)	Bone area (mm^2)	Bone density percentage (%)
Screws in dysplastic bone (n=13)	18.7	5.3	4.5	33.5
Screws in normal bone (n=4)	19.4	4.8	5.8	39.7

Table 3. Amount of direct bone contact with titanium screw perimeter

Mean value	Titanium perimeter (mm)	Bone contact (mm)	Bone contact percentage (%)
Screws in dysplastic bone (n=13)	10.8	2.72	25
Screws in normal bone (n=4)	10.4	4.6	44

Screws removed/ type of bone
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5 FD
4 FD 2 normal 2 FD 2 normal

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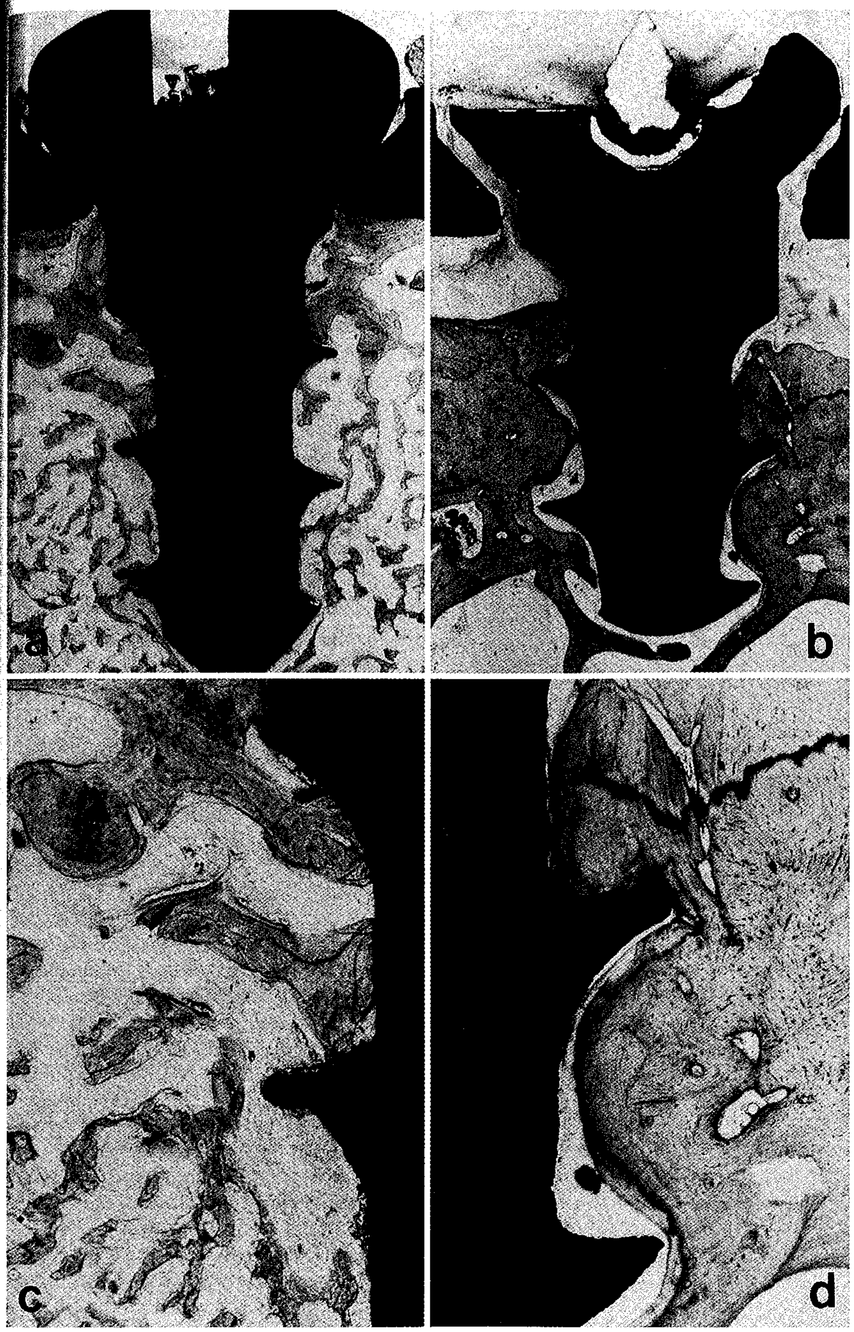

Fig. 2. Comparison of bone–screw interface in dysplastic and normal bone (toluidine blue). a) Screw in fibrous dysplastic bone (×20). b) Screw in contralateral normal bone of same patient (×20). c) Higher power view of (a), showing screw interface partly with dysplastic bone trabeculae and partly with fibrous stroma (×50). d) Higher power view of (b), showing screw interface partly with normal bone and partly with fibrous capsule (×50).

and normal bone groups were compared (BD: P=0.57; BCP: P=0.35).

Discussion

There are notable differences observable clinically and histologically between FD affecting the craniofacial regions and that which affects long bones. Most surgeons who have operated on long bones have noted that FD is soft, spongy, and easily cut by the surgical knife. The cortex was described as being so soft that sufficient anchorage was difficult to secure by direct bone wiring[14,17]. In contrast, Jackson et al.[15] stated that the FD of the craniofacial area is more fibro-osseous, with bony trabeculae predominating. These clinical impressions do have a histologic correlation. The classical histologic picture of FD in long bones is a cellular connective tissue arranged in a whorled pattern and containing irregularly shaped trabeculae of woven bone. The diagnosis of FD should be rejected if lamellar bone trabeculae are present or if osteoblasts are found to line the trabecular surface. However, FD of the skull and jawbone tends to be more osseous than in long bones. The presence of lamellar bone and osteoblastic rimming does not preclude a diagnosis of FD of the jaws, provided that the clinical, radiologic, and operative findings are compatible with this diagnosis[22,23]. A variable number of spherical, amorphous, and mineralized cementoid-like particles has also been noted in the jaw lesions[8,24].

Osteotomies in fibrous dysplastic bone are a challenge because of the distorted anatomy and the concern about fixation, which depends at least partially on bone of abnormal texture. Osteotomies have been performed in orthopedic cases of FD with adequate healing reported[9,12]. Although there are few reports of osteotomies performed in FD of the jawbone[3,16,19–21], the normal variety of orthognathic surgery can also be applied to these cases but with caution. Sagittal splitting of the mandibular ramus may be difficult due to loss of the natural anatomic plane between the cortical and cancellous bone. FD involving the maxilla tends to obturate the maxillary sinuses, and Le Fort I osteotomy requires sectioning through the solid bony mass. The descending palatine vessels can easily be damaged during downfracture, resulting in hemorrhage and potential vascular compromise. Similar care is needed when handling the vessels during removal of a bony wedge to facilitate maxillary impaction. Once the maxilla is downfractured without damage to its pedicle, standard segmentalization of the dysplastic maxilla can be performed with fixation by miniplates and screws. Surgical recontouring may be combined with osteotomies as a single-stage operation, and this concept of extended conservative surgery to maximize the aesthetic and functional results has been reported[20,21].

Fracture healing of FD in long bones is commonly complicated by fibrous union or nonunion. Closed reduction or direct wire osteosynthesis is considered not to provide sufficient stability for the healing process. Rigid fixation devices, such as intramedullary nailing, compression plating, or external fixation, which involve engagement of at least some normal bone, are the standard treatment to facilitate uneventful healing and eventual bony union[9,14,17].

In view of the more ossified nature of FD in the craniofacial area, a less rigid form of fixation may be adequate for osteotomies of the jaws with FD. Indeed, intermaxillary fixation in combination with either direct or suspensory wiring was sufficient for adequate healing in reports of Le Fort I osteotomy[19] and sagittal split osteotomy[3]. In a case of maxillary alveolar osteotomy, only an acrylic splint was sufficient for fixation[16]. In our four cases, however, titanium miniplates and screws were used for fixation of the osteotomized segments with the advantage of not requiring intermaxillary fixation. Rigid fixation with miniplates will also provide better stability, thus minimizing relapse of the surgical movement of segments. The lack of clinical change in postoperative occlusion and facial appearance supports this impression, but this needs to be confirmed in a larger series. This small study has nevertheless provided an opportunity to investigate the titanium screw fibrous dysplastic bone interface.

Direct bone contact with the titanium screws observed on light microscopy should not be interpreted as osseointegration. The current definition of osseointegration[1,2] is "a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant". This definition is based on observation at the implant–bone interface not only at the histologic but also at the ultrastructural level. At an ultrastructural level, the bone should be separated from the titanium oxide layer by only a few hundred angstroms of proteoglycans[13]. The definition is normally limited to dental implants because miniplates and screws do not carry any functional loading in the long term. Furthermore, the bone contact percentage of titanium dental implants in bone is normally in the range of 50–70% or above[7,10,11]. The mean bone contact percentage of the titanium screw with either the normal or dysplastic bone specimens in our study was considerably less in comparison. Therefore, this observed bone contact phenomenon can only be considered a form of mechanical interlocking of the screws with dysplastic bone. In normal bone, titanium screws used in miniplate fixation are also likely not to osseointegrate due to the formation of a fibrous capsule around an unpredictable portion of the screw perimeter, probably due to inadequate cooling during preparation of the screw hole by the drill. This was highlighted in the study of dental implants by ERIKSSON & ALBREKTSSON[6], who stated that a fibrous capsule, rather than direct bone contact, will occur if the heat generated by the drill in bone exceeds 47°C. This explains the lack of statistically significant difference in BCP between dysplastic and normal bone. However, the interpretation of this finding should also take into consideration the small sample size, the nonparametric distribution of the results, and the variable presentation of FD in the craniofacial region[4,18].

This study demonstrates the adequate biocompatibility of titanium screws with FD in the long term. Direct contact of the woven or lamellar bone with the screw surface was observed. We believe that miniplates and screws are an adequate form of fixation for osteotomies of jaws affected by FD. However, if the presentation includes a large cystic radiolucency or if the bone is noted to be very soft at biopsy, additional or alternative fixation should be considered.

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